remote sensing

Editorial

Assessing Sustainability over Space and Time: The Emerging Roles of GIScience and Remote Sensing

Ronald C. Estoque

Center for Biodiversity and Climate Change, Forestry and Forest Products Research Institute, 1 Matsunosato, Tsukuba 305-8687, Japan; estoquerc21@affrc.go.jp

Sustainability is a critical global challenge that requires comprehensive assessments of environmental, social, and economic indicators. The formulation of the 17 Sustainable Development Goals (SDGs) represents a significant leap forward in humanity's pursuit of sustainability. The SDGs now serve as a platform for global development, guiding current actions and shaping visions for a sustainable future. Tracking the spatiotemporal dynamics of progress towards the SDGs and sustainability in general is essential, not only at global and national scales, but also at subnational and landscape levels. Geographic Information Science (GIScience) and Remote Sensing (RS) have made significant advancements, including the increase in availability of geospatial data, which can play a crucial role in this regard.

GIScience focuses on spatial data, information systems, and technologies for managing, analyzing, and visualizing spatial information. GIScience can help identify patterns and trends, assess sustainability-related indicators, evaluate the effectiveness of policies and management strategies, and support decision-making processes. RS, on the other hand, involves the acquisition and interpretation of data about the Earth's surface and atmosphere from RS platforms such as satellites, airplanes, or drones. RS provides a wide range of spatial data, such as land cover, vegetation indices, and atmospheric parameters, which can be used to monitor and assess sustainability-related indicators.

This Special Issue aims to bring together novel contributions on the assessment of sustainability and sustainability-related indicators over space and time using geospatial data, tools, and techniques (GIScience and RS). It consists of eleven peer-reviewed papers, including two review articles and nine research articles.

The first review article focuses on the concept of sustainability and the state of SDG monitoring using RS [1]. It traces the conceptual origins of sustainability and discusses the role of RS in SDG monitoring, as well as the current status, challenges, and opportunities. The review reveals that the pursuit of a sustainable future likely began in the 17th century when declining forest resources in Europe led to proposals for the re-establishment and conservation of forests, embodying the great idea that the current generation bears responsibility for future generations. As of April 2020, preliminary statistical data were available for 21 (70%) of the 30 RS-based SDG indicators, according to the Global SDG Indicators Database, with 10 (33%) also included in the 2019 SDG Index and Dashboards. However, at the time of the review, these statistics may not have necessarily reflected the actual status and availability of raw and processed geospatial data for RS-based indicators, which is an important issue to consider. Nevertheless, the review also identifies various initiatives that have been initiated to address data-related issues, which are crucial for SDG monitoring.

The second review article explores the role of RS in international peace and security [2]. Specifically, it examines the key research concepts and implementation of RS for applications related to international peace and security. The article presents a meta-analysis of how advanced sensor capabilities can support various aspects of peace and security, including relief operations, monitoring armed conflicts, tracking acts of genocide, international peace missions, human rights, and disease control and prevention. The review concludes that

Citation: Estoque, R.C. Assessing Sustainability over Space and Time: The Emerging Roles of GIScience and Remote Sensing. *Remote Sens.* **2023**, *15*, 2764. https://doi.org/10.3390/rs15112764

Received: 25 April 2023
Accepted: 9 May 2023
Published: 26 May 2023

RS, as a surveillance tool, has immense potential in safeguarding the environment, peace, and security, provided it is used actively and transparently. However, there are future challenges that may hinder the application of RS in peace and security, such as discrepancies in image classifications due to varying types of sensors, as well as issues related to cost, resolution, and ground-truth validation in conflict areas. Nevertheless, with emerging technologies and sufficient secondary resources available, the article argues that RS will continue to be an important tool in aiding peacekeeping processes in conflict-affected areas.

The nine research articles can be grouped into two: (1) index and framework development, and (2) social–ecological research applications. The remotely sensed urban surface ecological index (RSUSEI) is proposed as an index to assess urban surface ecological status, which is influenced by surface biophysical, biochemical, and biological properties [3]. The RSUSEI is developed using five RS-derived variables, namely the normalized difference vegetation index, normalized difference soil index, wetness index, land surface temperature, and impervious surface cover, based on principal component analysis. The RSUSEI was successfully applied in six cities across the United States, and the study concludes that it has significant potential for modeling and comparing urban surface ecological status in cities with diverse geographical, climatic, environmental, and biophysical conditions.

Another proposed index, called the improved comprehensive remote sensing ecological index (IRSEI), is designed for evaluating urban ecological quality [4]. The IRSEI incorporates four RS-derived ecological elements, including humidity, greenness, heat, and dryness, and is constructed using a combination of entropy weight and principal component analysis. The index has been applied in Wuhan, China, and the study concludes that IRSEI, along with the urban ecological quality approach in general, can be a valuable tool for ecological management and protection, as well as for assessing progress towards urban sustainable development.

A new framework, based on GIScience and spatial justice (fair allocation), has been proposed with a focus on the sustainable development of life service resources [5]. This framework addresses two key questions: (1) why spatial justice should be considered when studying life service resources, and (2) how spatial justice should be applied and interpreted for life service resources. The framework has been applied in Beijing, China, using multi-source data such as population density and building outlines, and GIScience methods such as nearest neighbour and kernel density analysis. Based on the findings, the study recommends that future planning should aim to narrow the development gap through the optimal spatial allocation of life service resources to improve spatial justice.

Among the research application articles is a study that focuses on the impacts of urbanization on the Muthurajawela Marsh and Negombo Lagoon in Sri Lanka, which is an important wetland ecosystem providing a wide range of ecosystem services [6]. Using multi-temporal RS and other spatial data, the study found that the spatial and socioeconomic elements of rapid urbanization in the area have been the main drivers of the wetland's environmental transformation over the past 20 years (1997–2017). This is evident from the substantial expansion of settlements (+68%) and significant decrease in marshland and mangrove cover (−41% and −21%, respectively). The study concludes that there is an urgent need for forward-looking landscape and urban planning to ensure the sustainability of this valuable wetland ecosystem.

Another contribution focuses on multi-temporal mapping of population distribution using RS data and deep learning techniques [7]. The study argues that understanding the spatiotemporal distribution of population is crucial in various fields, such as resource management, disaster response, public health, and urban planning, all of which are relevant to the sustainability goal. However, the study observes that there is a lack of continuous, multi-temporal gridded population data over a long historical period, and attributes this to the absence of appropriate auxiliary datasets and effective methodological frameworks. The study aims to address this knowledge gap by proposing a methodological framework that integrates deep learning architecture and Landsat data, which has been applied in

China. The study concludes that this proposed framework can be particularly useful in low-income and data-poor regions.

Understanding the relationship between eco-environmental quality and urbanization has been a focal point of another contribution [8]. The study argues that comprehending the interactive coupling mechanism between eco-environmental quality and urbanization is of great significance in achieving urban sustainability. The study focuses on China as a case study and utilizes multi-source RS data and the coupling coordination degree model to facilitate the analysis. The findings of the study reveal that rapid urbanization has resulted in a significant decline in eco-environmental quality in certain areas of the country. The authors emphasize the need to prioritize the protection of the ecological environment while pursuing social and economic development in the future.

A contribution focusing on the neighborhood level in Guilin, China, assessed the spatiotemporal changes of three SDG indicators (11.2.1, 11.3.1, and 11.7.1) using high-resolution RS images and a big data approach [9]. The study found that the proportion of the population with convenient access to public transport gradually improved from 42% in 2013 to 52% in 2020. However, the increase in built-up land was relatively fast, resulting in a decrease in the areal proportion of public open space from 56% in 2013 to 24% in 2020. The authors highlight the role of big data and Earth observation technology in monitoring urban sustainable development. This study provides an example of a neighborhood-level assessment of SDG indicators, which is crucial for local urban governance and planning practices.

Also focusing on SDG 11, a case study in Manila, Philippines, assessed the urban heat island phenomenon using RS data [10]. Consistent with findings from other studies around the world, the study revealed that residential areas, asphalted and concrete roads and walkways, and certain commercial establishments and buildings exhibited higher surface temperatures compared to areas with vegetation and near bodies of water. The study proposed strategies to mitigate the impacts of urban heat islands, including the use of cool materials for pavements and roofs; the conversion of regular walls to green walls; and increased planting in plant boxes, road isles, and indoors. The authors also recommended the establishment of additional meteorological stations in urban heat island hotspots to help improve the current understanding of outdoor thermal characteristics in the city.

Finally, in Mexico, a case study assessed the drivers that influence the dynamics of a tropical dry forest in Ayuquila River watershed using multi-temporal RS and other spatial data [11]. The study estimated a tropical dry forest loss rate of 1.6% per year between 2019 and 2022. The study also identified an inverse relationship between forest loss and slope and distance to roads. This is related to the fact that flat areas are preferred for agricultural and livestock activities due to easy access and lower costs. Careful consideration of these factors is essential when addressing tropical dry forest loss in the region. The loss of tropical dry forests not only contributes to carbon loss, but also leads to biodiversity loss, soil erosion, and increased vulnerability of local communities that rely on these forests for sustenance and shelter.

In summary, GIScience and RS and their integration have emerged as valuable tools for assessing sustainability and sustainability-related indicators over space and time. This Special Issue contributes to the growing body of knowledge in this area, underscoring the crucial roles of GIScience and RS in advancing sustainability assessment and research.

Funding: This work was supported by the Japan Society for the Promotion of Science (JSPS) through its Grants-in-Aid for Scientific Research (KAKENHI) Program: Grant-in-Aid for Scientific Research (C), Number 22K01038 (Principal Investigator: Ronald C. Estoque). The views expressed in this paper are of the author and do not necessarily reflect the position of his institution and of the funder.

Acknowledgments: The author (Special Issue Guest Editor) wishes to thank the authors for their valuable contributions to this Special Issue. Likewise, to the Editors and Reviewers for their expertise, time, and effort.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Estoque, R.C. A Review of the Sustainability Concept and the State of SDG Monitoring Using Remote Sensing. *Remote Sens.* **2020**, *12*, 1770. [CrossRef]
2. Avtar, R.; Kouser, A.; Kumar, A.; Singh, D.; Misra, P.; Gupta, A.; Yunus, A.P.; Kumar, P.; Johnson, B.A.; Dasgupta, R.; et al. Remote Sensing for International Peace and Security: Its Role and Implications. *Remote Sens.* **2021**, *13*, 439. [CrossRef]
3. Firozjaei, M.K.; Fathololoumi, S.; Weng, Q.; Kiavarz, M.; Alavipanah, S.K. Remotely Sensed Urban Surface Ecological Index (RSUSEI): An Analytical Framework for Assessing the Surface Ecological Status in Urban Environments. *Remote Sens.* **2020**, *12*, 2029. [CrossRef]
4. Li, J.; Gong, J.; Guldmann, J.-M.; Yang, J. Assessment of Urban Ecological Quality and Spatial Heterogeneity Based on Remote Sensing: A Case Study of the Rapid Urbanization of Wuhan City. *Remote Sens.* **2021**, *13*, 4440. [CrossRef]
5. Xu, Z.; Niu, L.; Zhang, Z.; Huang, J.; Lu, Z.; Huang, Y.; Wen, Y.; Li, C.; Gu, X. Sustainable Development of Life Service Resources: A New Framework Based on GIScience and Spatial Justice. *Remote Sens.* **2022**, *14*, 2031. [CrossRef]
6. Athukorala, D.; Estoque, R.C.; Murayama, Y.; Matsushita, B. Impacts of Urbanization on the Muthurajawela Marsh and Negombo Lagoon, Sri Lanka: Implications for Landscape Planning towards a Sustainable Urban Wetland Ecosystem. *Remote Sens.* **2021**, *13*, 316. [CrossRef]
7. Zhuang, H.; Liu, X.; Yan, Y.; Ou, J.; He, J.; Wu, C. Mapping Multi-Temporal Population Distribution in China from 1985 to 2010 Using Landsat Images via Deep Learning. *Remote Sens.* **2021**, *13*, 3533. [CrossRef]
8. Xu, D.; Cheng, J.; Xu, S.; Geng, J.; Yang, F.; Fang, H.; Xu, J.; Wang, S.; Wang, Y.; Huang, J.; et al. Understanding the Relationship between China's Eco-Environmental Quality and Urbanization Using Multisource Remote Sensing Data. *Remote Sens.* **2022**, *14*, 198. [CrossRef]
9. Han, L.; Lu, L.; Lu, J.; Liu, X.; Zhang, S.; Luo, K.; He, D.; Wang, P.; Guo, H.; Li, Q. Assessing Spatiotemporal Changes of SDG Indicators at the Neighborhood Level in Guilin, China: A Geospatial Big Data Approach. *Remote Sens.* **2022**, *14*, 4985. [CrossRef]
10. Purio, M.A.; Yoshitake, T.; Cho, M. Assessment of Intra-Urban Heat Island in a Densely Populated City Using Remote Sensing: A Case Study for Manila City. *Remote Sens.* **2022**, *14*, 5573. [CrossRef]
11. Gao, Y.; Solórzano, J.V.; Estoque, R.C.; Tsuyuzaki, S. Tropical Dry Forest Dynamics Explained by Topographic and Anthropogenic Factors: A Case Study in Mexico. *Remote Sens.* **2023**, *15*, 1471. [CrossRef]